

Electroweak-ino via Vector Boson Fusion

Bhaskar Dutta

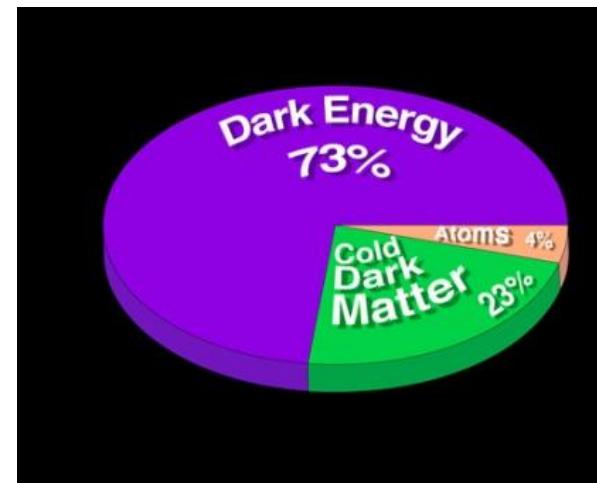
Texas A&M University

Energy Frontier Meeting : BNL

LHC and Dark Matter

→ LHC is very efficient in producing colored particles

→ Annihilation cross-section of Dark Matter particles generates dark matter content of the universe



→ Annihilation cross-section strength mostly depend on the colorless particles, e.g., sleptons, staus, charginos, neutralinos, etc.

→ Usual method to probe these non-colored particles:
Cascade decays of squarks and gluinos

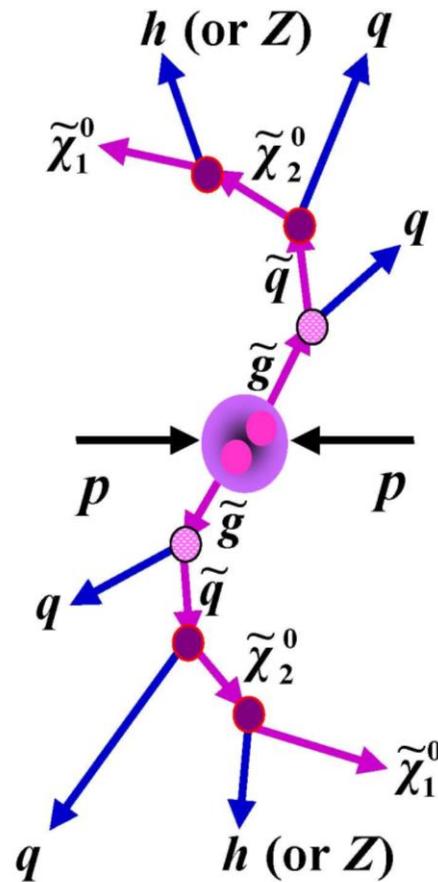
Dark Matter at the LHC

Determining the nature of dark matter from the Cascade decays

Is the neutralino a Bino, Wino or Higgsino?

Very difficult to establish!

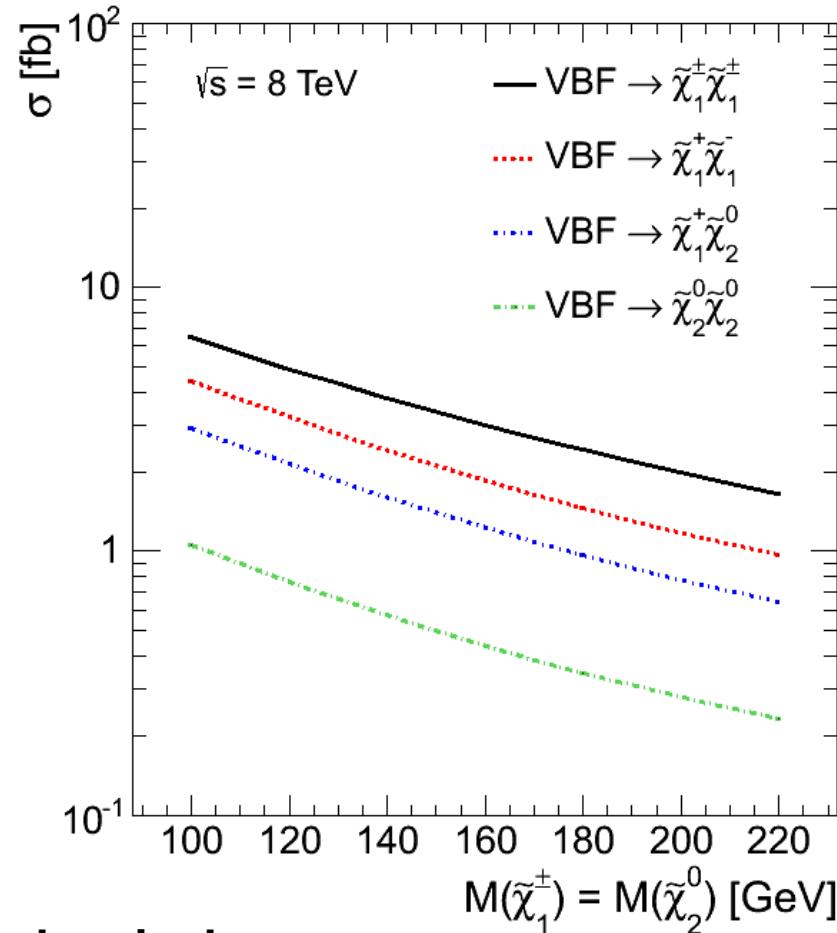
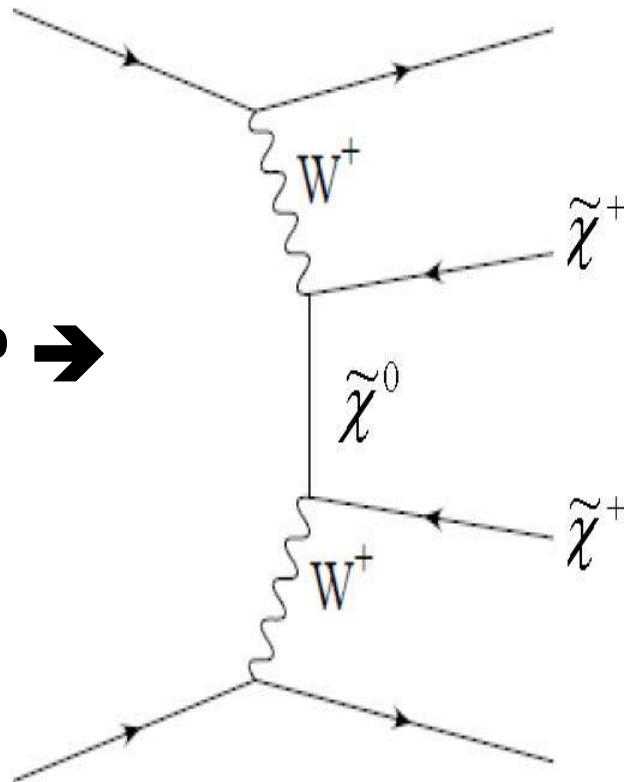
We need to produce them directly!



DM at the LHC Via VBF

Direct probes of charginos, neutralinos and sleptons

$P + P \rightarrow$



Two high E_T forward jets in opposite hemispheres
with large dijet invariant mass

VBF studies

1. $pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_1^\pm jj, \tilde{\chi}_1^\pm \tilde{\chi}_1^\mp jj, \tilde{\chi}_1^\pm \tilde{\chi}_2^0 jj, \tilde{\chi}_2^0 \tilde{\chi}_2^0 jj$
2. $pp \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 jj$
3. $pp \rightarrow \tilde{e}\tilde{e}jj, \tilde{\mu}\tilde{\mu}jj, \tilde{\tau}\tilde{\tau}jj, \tilde{\mu}\tilde{\nu}jj, \tilde{\tau}\tilde{\nu}jj$



VBF studies

1. $pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_1^\pm jj, \tilde{\chi}_1^\pm \tilde{\chi}_1^\mp jj, \tilde{\chi}_1^\pm \tilde{\chi}_2^0 jj, \tilde{\chi}_2^0 \tilde{\chi}_2^0 jj$

For : $m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_2^0} > m_{\tilde{l}} > m_{\tilde{\chi}_1^0}$

Signal: $\geq 2j + 2\tau + \text{missing energy}, \quad \geq 2j + 2\mu + \text{missing energy}$

For Heavy Sleptons:

Signal: $2 j + WW, WZ, ZZ + \text{missing energy},$



Background: W+ jets, Z+ jets, WW, ZZ, t t etc.

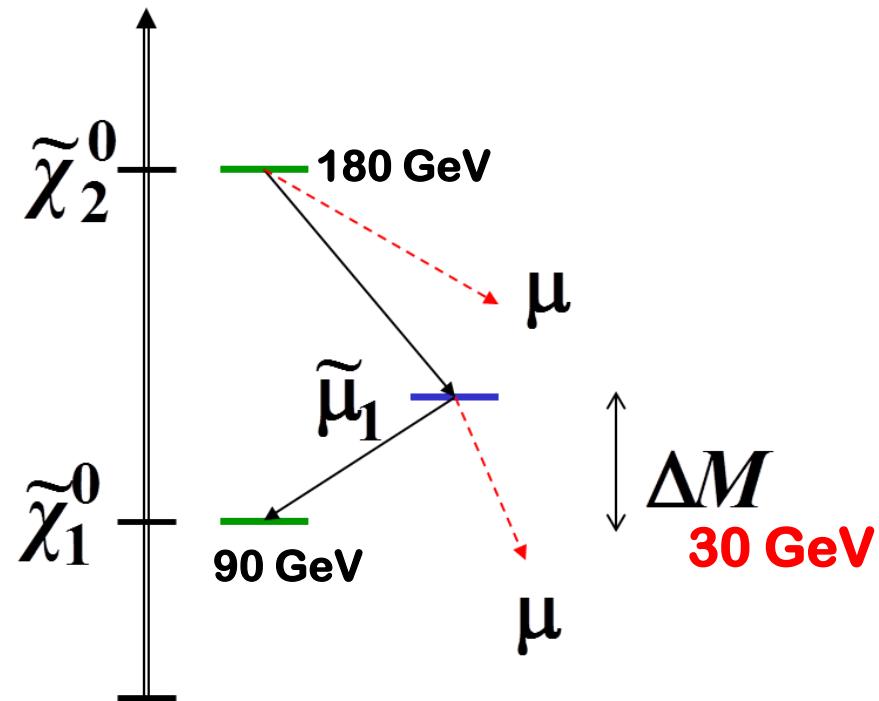
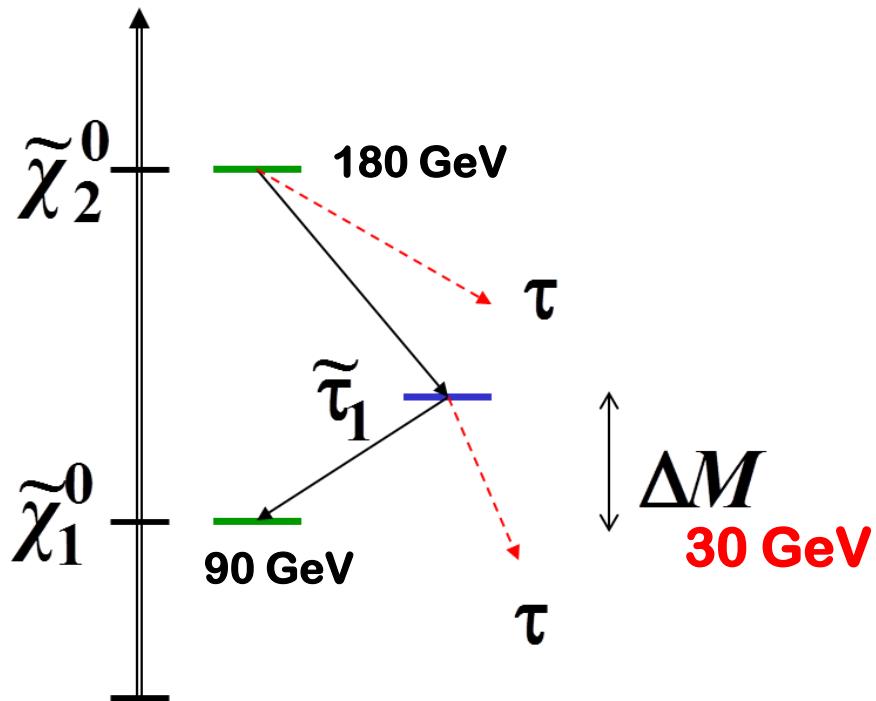
1. Charginos, Neutralinos via VBF

2 jets with $p_T(j) > 50 \text{ GeV}$; $p_T(j_1) > 75 \text{ GeV}$

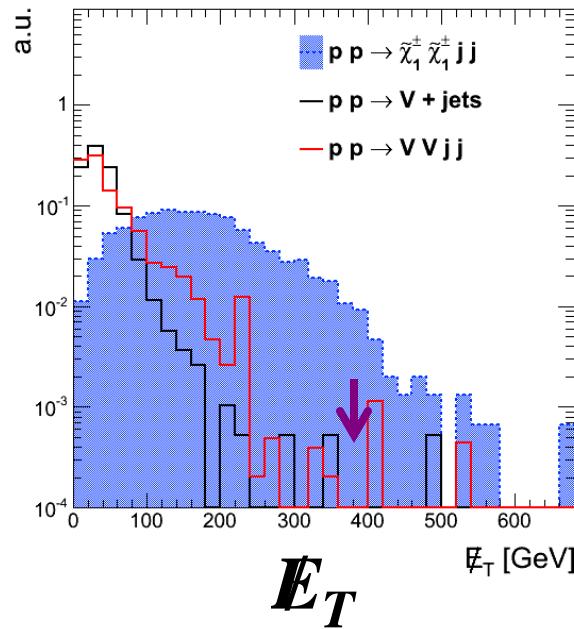
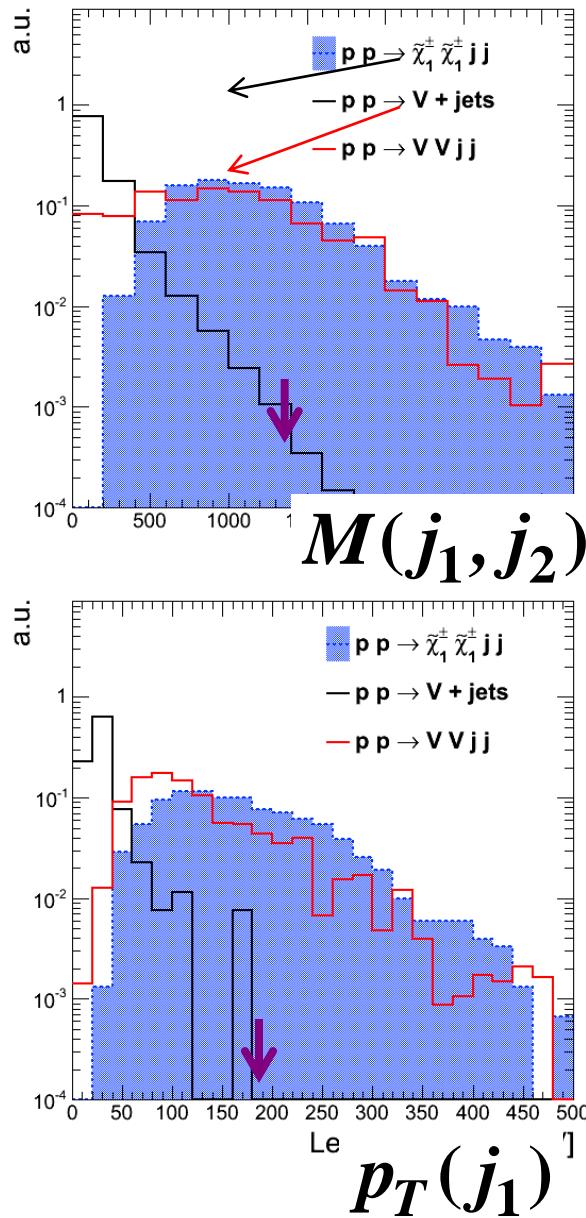
$|\Delta\eta| > 4.2$; $\eta_1 \cdot \eta_2 < 0$

$M(j_1, j_2) > 650 \text{ GeV}$; MET $> 75 \text{ GeV}$

2 Benchmark Scenarios



VBF Kinematics



$$M(\tilde{\chi}_1^+) \sim M(\tilde{\chi}_2^0) = 180 \text{ GeV}$$

$$M(\tilde{\chi}_1^0) = 90 \text{ GeV}$$

$$M(\tilde{\tau}_1^+) - M(\tilde{\chi}_1^0) = 30 \text{ GeV}$$

→ Large MET, large $M(jj)$, large p_T jets

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Signal: $\geq 2j + 2\tau + \text{missing energy}$

2 jets each with $p_T > 50 \text{ GeV}$, leading $p_T > 75 \text{ GeV}$
 $|\Delta\eta(j_1, j_2)| > 4.2$, $\eta_{j1}\eta_{j2} < 0$, $M_{j1j2} > 650 \text{ GeV}$

Signal: $\geq 2j + 2\tau + \text{missing energy}$

$$m_{\tilde{\chi}_1^\pm} \sim m_{\tilde{\chi}_2^0} = 180 \text{ GeV},$$

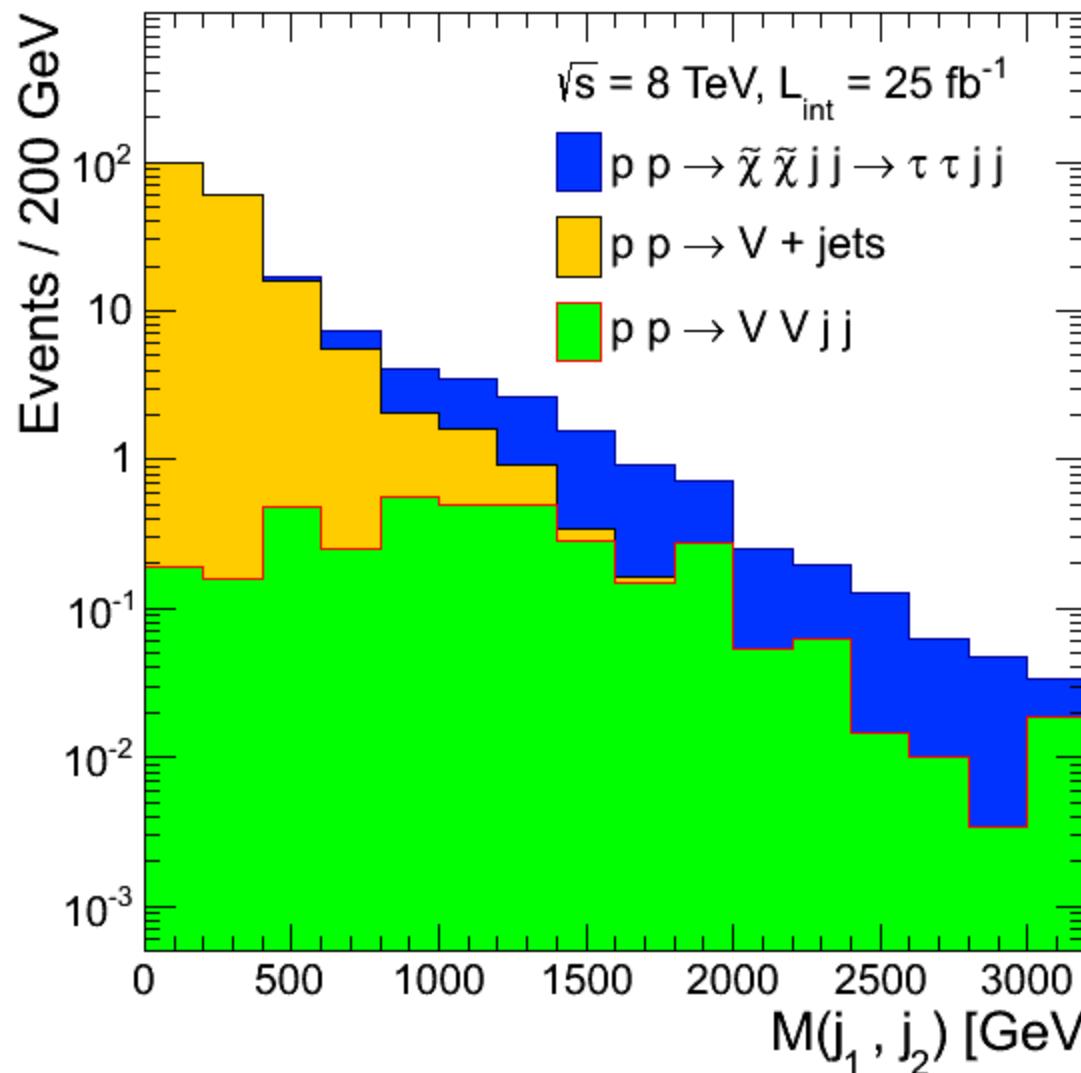
$$\sqrt{s} = 8 \text{ TeV}$$

$$\text{Lum: } 25 \text{ fb}^{-1}$$

	Signal	Z+jets	W+jets	WW	WZ
VBF cuts	4.61	10.9	3.70×10^3	97.0	19.0
$E_T > 75$	4.33	0.27	5.29×10^2	17.6	3.45
2τ , inclusive	0.45	0.06	0.23	0.09	0.04
(S/\sqrt{B})			3.47		
$\tau^\pm\tau^\pm$	0.21	0	0.11	0.02	0.01
(S/\sqrt{B})			2.91		
$\tau^\pm\tau^\mp$	0.24	0.06	0.12	0.07	0.03
(S/\sqrt{B})			2.27		

Two τ 's with $p_T > 20 \text{ GeV}$ in $\eta < 2.1$, with $\Delta R(\tau\tau) > 0.3$. All τ 's are hadronic
The τ ID efficiency is assumed to be 55% and the jet $\rightarrow \tau$ Mis-identification rate is taken to be 1%,

Signal: $\geq 2j + 2\tau + \text{missing energy}$



Signal: $\geq 2j + 2\mu + \text{missing energy}$

2 jets each with $p_T > 50 \text{ GeV}$, leading $p_T > 75 \text{ GeV}$
 $|\Delta\eta(j_1, j_2)| > 4.2, \eta_{j1}\eta_{j2} < 0, M_{j1j2} > 650 \text{ GeV}$

Signal: $\geq 2j + 2\mu + \text{missing energy}$ $m_{\tilde{\chi}_1^\pm} \sim m_{\tilde{\chi}_2^0} = 180 \text{ GeV},$

	Signal	$Z + \text{jets}$	$W + \text{jets}$	WW	WZ
VBF cuts	4.61	10.9	3.70×10^3	0.97×10^2	19.0
$E_T > 75$	4.33	0.27	5.29×10^2	17.6	3.45
2μ , inclusive	1.83	0.15	0	0.12	0.19
(S/\sqrt{B})			13.5		
$\mu^\pm \mu^\pm$	0.87	0	0	0.03	0.05
(S/\sqrt{B})			15.4		
$\mu^\pm \mu^\mp$	0.96	0.15	0	0.09	0.14
(S/\sqrt{B})			7.80		

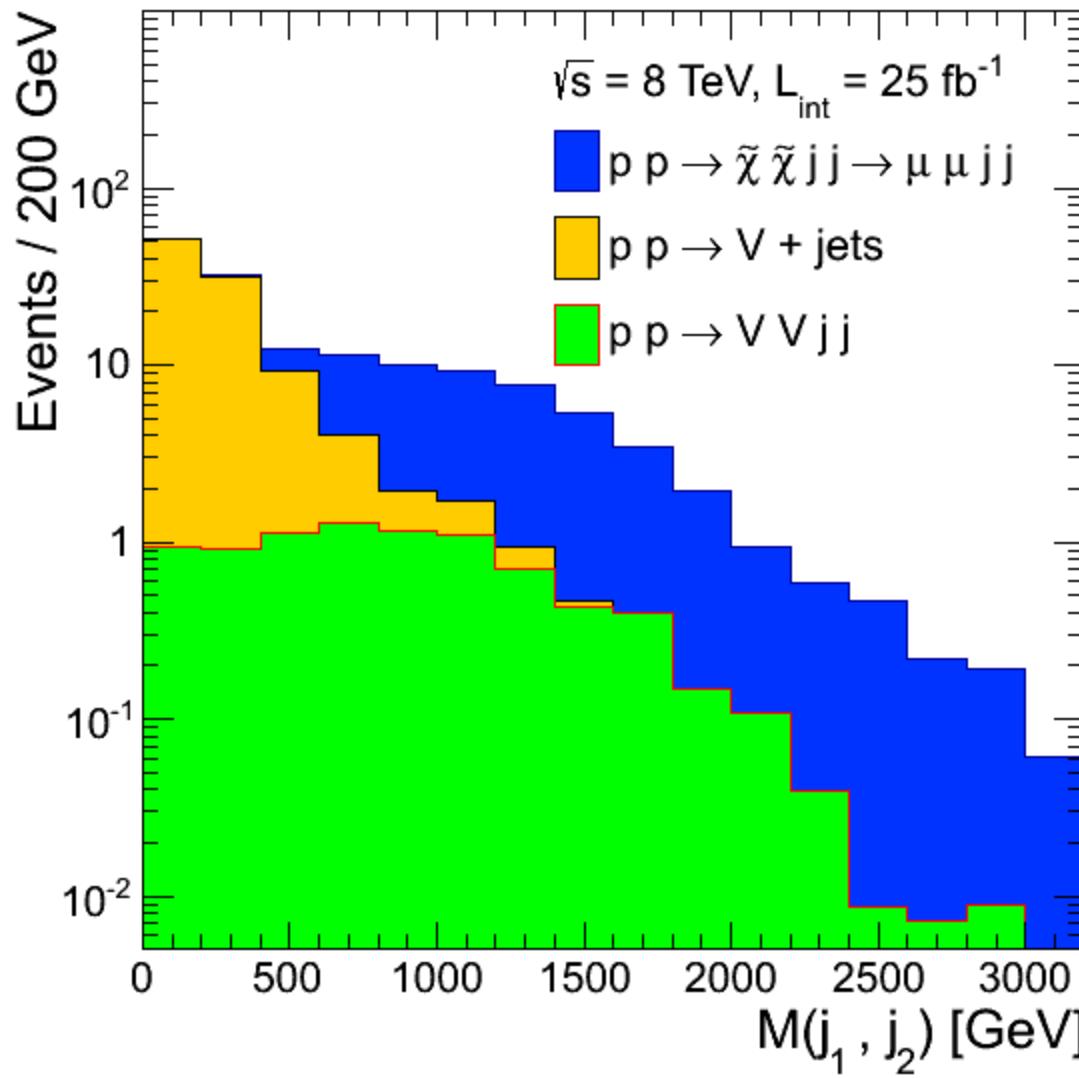
$\sqrt{s} = 8 \text{ TeV}$

Lum: 25 fb^{-1}

Two isolated μ 's with $p_T > 20 \text{ GeV}$ in $\eta < 2.1$

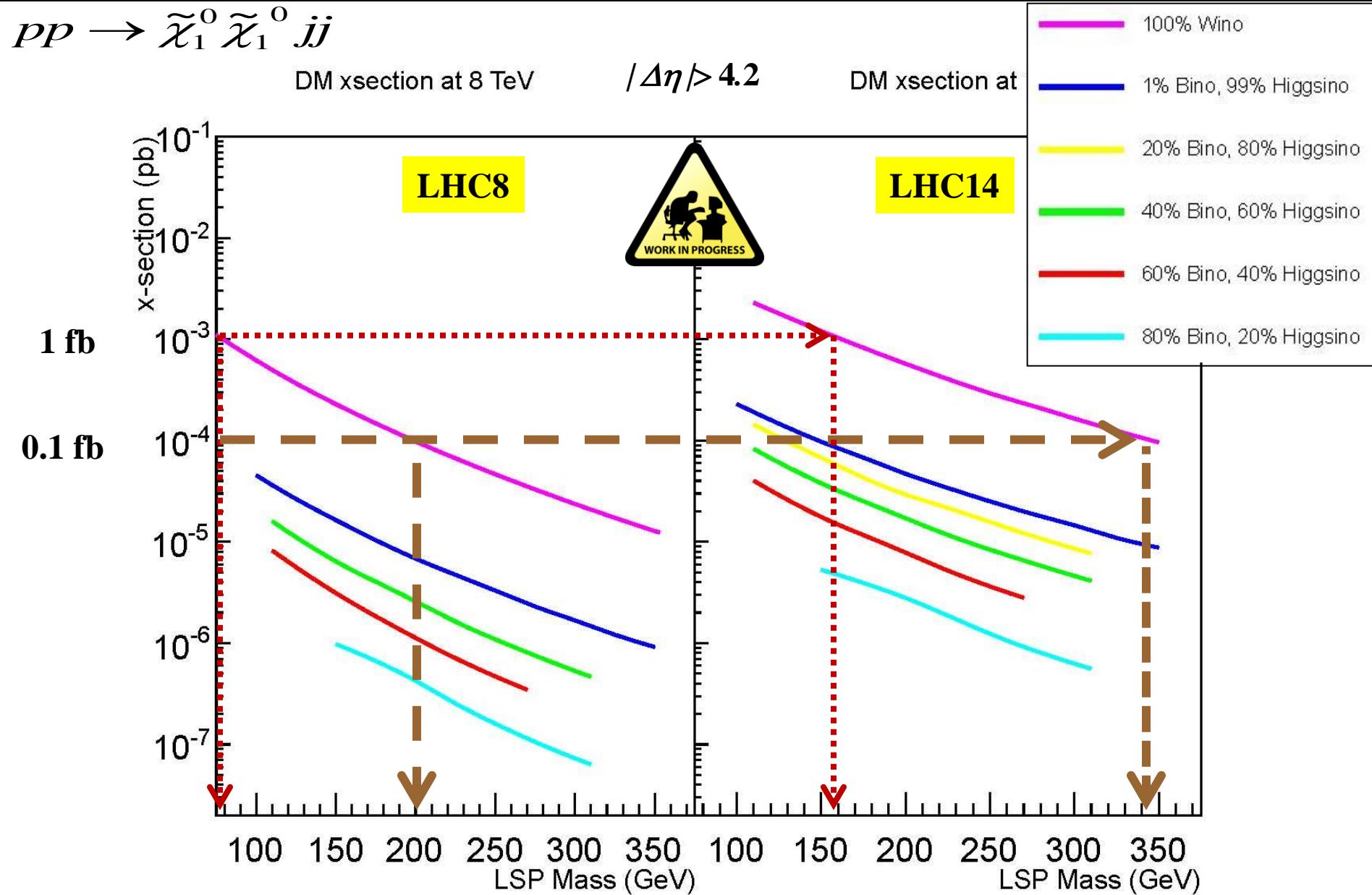
For 3σ : $m_{\tilde{\chi}_1^\pm} \sim m_{\tilde{\chi}_2^0} = 330 \text{ GeV}$

Signal: $\geq 2j + 2\mu + \text{missing energy}$



2. Lightest neutralinos via VBF

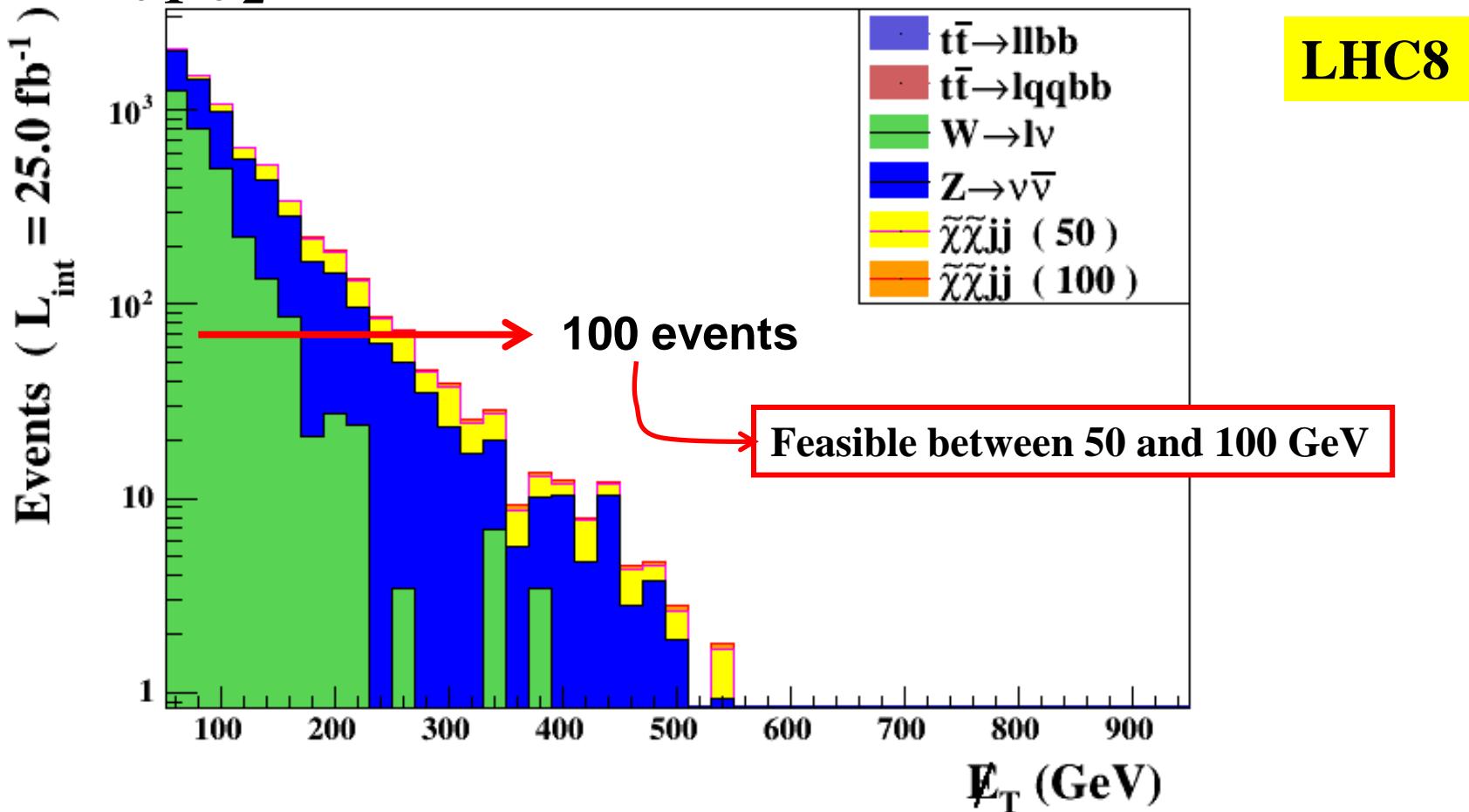
$$pp \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 jj$$



Wino-DM MET

2 jets with $p_T(j) > 50 \text{ GeV}$; $|\Delta\eta| > 4.2$; $\eta_1 \cdot \eta_2 < 0$

$M(j_1, j_2) > 1500 \text{ GeV}$; MET $> 300 \text{ GeV}$



Wino DM...

$pp \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 jj$ LHC 8 TeV: $m_{\tilde{\chi}_1^0} = 50$ GeV

	Signal	$Z + \text{jets}$	$W + \text{jets}$	$t\bar{t}$	Significance
VBF cuts					
(i) preselection	4.61	10.9	3.70×10^3	97.0	19.0
(ii) Tagged jets p_T	4.61	10.9	3.70×10^3	97.0	19.0
(iii) $M_{j_1 j_2} > 1500$	4.61	10.9	3.70×10^3	97.0	19.0
Vetoies					
(i) Central jet	4.61	10.9	3.70×10^3	97.0	19.0
(ii) b jet	4.61	10.9	3.70×10^3	97.0	19.0
(iii) Lepton	4.61	10.9	3.70×10^3	97.0	19.0
$\cancel{E}_T > 300$ GeV	4.33	0.27	5.29×10^2	17.6	3.45

O(few hundred) GeV Wino DM is possible at the 14 TeV LHC

Soft leptons from chargino decay for Wino LSP @ 14 TeV LHC



Conclusion

- Annihilation cross-section of DM particles is mostly dominated by the particles without any color charge
- These particle are mostly studied from the cascade decays of new colored particle since direct production is small and the signal suffers from large background
- We use VBF production of these particles utilizing two high E_T jets in opposite hemispheres
- We are studying productions of charginos, neutralinos, sleptons, spin of DM particle etc. for 14 TeV LHC and higher energy hadron collider

Backup

Sleptons via VBF

